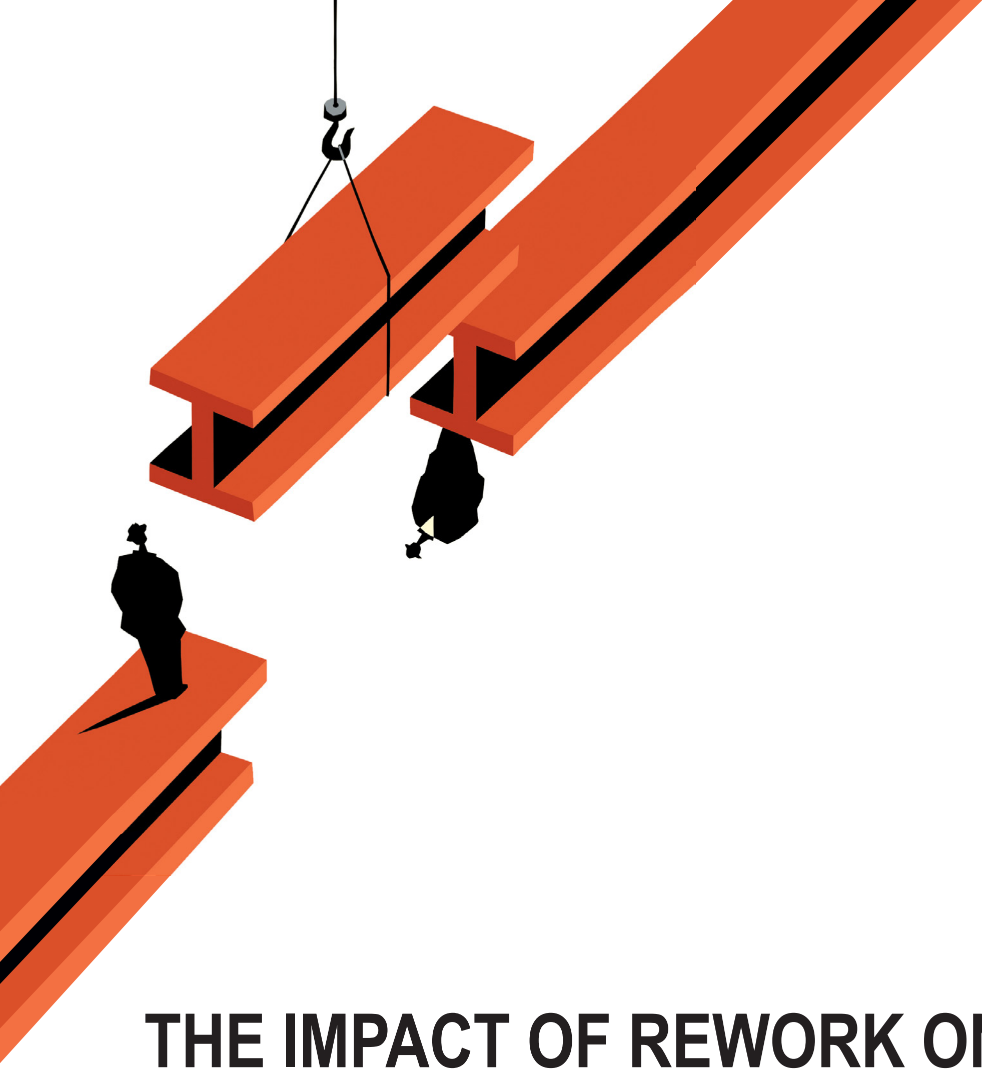

THE IMPACT OF REWORK ON CONSTRUCTION & SOME PRACTICAL REMEDIES

A Research Perspective Issued by the

Navigant Construction Forum™

Jason M. Dougherty
LEED AP[1]
Associate Director

Nigel Hughes
LEED AP[2]
Associate Director

James G. Zack, Jr.
CCM, CFCC, FAACEI, FRICS, PMP[3]
Executive Director
Navigant Construction Forum™

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Building on the lessons learned in construction dispute avoidance and resolution.™

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Purpose of Research Perspective

Navigant Consulting and the Navigant Construction Forum™ were recently challenged to research and provide an estimate of the "average cost of rework on construction projects". Rework in the construction industry is frequent and well known on most construction projects globally. It is a drain on productivity, profitability and timeliness of project delivery for both contractors and owners. Additionally, the need for rework can have spinoff or downstream impacts for all project stakeholders. The causes of rework are, likewise, very well known: design and construction changes; errors and omissions; project enhancements; operability changes; fabrication changes and errors, etc. And the list of the causes of rework goes on.

While rework is common in construction, the impact has not been thoroughly assessed, studied or discussed. This research perspective, based on a broad literature review, assesses and identifies the typical cost of rework on a wide range of project types. It further shows how the identified cost of rework is frequently understated and provides an estimate of the true "average cost" of rework. Additionally, using industry studies, the research perspective identifies the average impact of rework on project duration in terms of time as well as unrecoverable extended overheads and the cost of liquidated or late completion damages.

After examining the literature to determine the impact of rework on various types of capital improvement projects, the Navigant Construction Forum™ identified a number of practical methods that can be employed by owners and contractors to substantially reduce both the cost and time impact of rework.

Introduction

One of the authors of this research perspective was told more than 30 years ago, "While there never seems to be enough time to do work right the first time, there's always enough time to do it over again." The senior construction manager who made this comment was referring to a common problem on construction projects – the need to perform rework during the life of the project. His comment was meant to instill in a group of younger construction managers the critical need to plan and execute work in a manner that avoids the need for rework. To illustrate the impact of rework this same construction manager pointed out that, in his experience, "it takes 90% of the time to perform the first 90% of the work and the other 90% of the time to perform the last 10%. "While this latter statement is hyperbole, it is understood that rework consumes time and costs money on any project. This research perspective is intended to provide information concerning the impact – both cost and time – resulting from the need to perform rework on construction projects. Further, this research perspective offers some practical ways to avoid the need for rework which, if successfully employed, should result in both cost and time savings for all project stakeholders.

Definition of "Rework"

At the outset, the Navigant Construction Forum™ reviewed available literature to obtain a definition of the term "rework"; a term that is frequently used but quite rarely defined well. The best definition seems to be the following:

> "Activities in the field that have to be done more than once in the field, or activities which remove work previously installed as part of the project regardless of source, where no change order has been issued and no change of scope has been identified by the owner."[4]

The authors of the referenced article went on to discuss what field rework was <u>not</u>, in the following manner:

- Project scope changes;
- Design changes or errors that do <u>not</u> affect field construction activities;
- Additional or missing scope due to designer or constructor errors (<u>but</u> rework does include the cost associated with redoing portions of work that incorporate or interface with additional or missing scope);
- Offsite fabricator errors that are corrected <u>off-site</u>;
- Offsite modular fabrication errors that are corrected <u>off-site</u>;
- Onsite fabrication errors that do <u>not</u> affect direct field activities (i.e., that are corrected without disrupting the flow of construction activities.

While the Navigant Construction Forum™ acknowledges that offsite fabrication errors that are remedied offsite may not cause onsite rework, as discussed later in this research perspective, such offsite rework may well impact the time of performance of onsite work, thus adversely impacting the timely delivery of the project. Therefore, offsite rework efforts should be taken into account when calculating the time impact of rework.

The authors of the above referenced article also went on to state that "Any change to the project scope (scope changes) should not be considered as field rework." However, the Navigant Construction Forum™ believes that, if such scope changes require removal of work already installed in order to accommodate the scope change, then the removal effort should be classified as rework.

Causes of Rework

In what is apparently the most frequently cited article on the causes of rework, Burati, Farrington and Ledbetter discussed the causes of "quality deviations" in design and construction. They defined the term "quality deviation" in the following manner.

> "*Quality* is defined as 'conformance to established requirements.' … The term *deviation* indicates that a product or result that does not fully conform to all specification requirements… *Deviation* includes changes to the requirements that result in rework…"[5]

The authors surveyed all Construction Industry Institute ("CII") members initially to learn about the causes of rework. They limited the next step of their research to industrial projects with $5.0 million or more in Total Installed Cost ("TIC") that were completed in the mid-1980s. Each project included in the survey had a different designer and contractor. They then performed an in-depth study of nine projects that met these criteria.

From the in-depth study of these projects, the authors determined 19 potential causes of deviations that may cause or result in rework to engineering and construction projects. These 19 causes are listed below[6]:

DEVIATION CATEGORY	DESCRIPTION
Construction change	Change in method of construction
Construction error	Error made during construction
Construction omission	Omission made during construction
Design change / improvement	Design revision, modification or improvement
Design change / construction	Design change initiated by construction contractor or owner's construction manager
Design change / field	Design change required due to field conditions (i.e., lack of as-builts, differing site conditions, etc.)
Design change / owner	Design change initiated by owner
Design change / process	Design change initiated by operations or process staff
Design change / fabrication	Design change initiated by fabricator
Design change / unknown	Design change with an unknown source of initiation
Design error	Error made during design
Design omission	Omission made during design

DEVIATION CATEGORY	DESCRIPTION
Operability change	Change made to improve operability
Fabrication change	Change made during fabrication
Fabrication error	Error made during fabrication
Fabrication omission	Omission made during fabrication
Transportation change	Change made to method of transportation
Transportation error	Error made in method of transportation
Transportation omission	Omission made in transportation

Estimate of the Cost of Rework

CII has developed a simple formula for quantifying the impact of rework on construction cost.[7] The formula is set forth below:

$$\text{Total Field Rework Factor ("TFRF")} = \frac{\text{Total direct cost of field rework}}{\text{Total construction cost}}$$

In performing a literature review concerning the average TFRF cost, the Navigant Construction Forum™ reviewed a number of studies. Some studies calculated TFRF simply as a percentage of construction costs across all projects studied. Other studies parsed the studied projects into type of project and/or size of project. In the summary below in which the Navigant Construction Forum™ cites a study that simply reported TFRF as a percentage of all projects studied the team included that percentage. When citing studies that disaggregated the type and size of projects studied, the Forum included the TFRF for those projects separately.

Set forth below is a summary of the various studies reviewed and the results of these studies concerning the percentage of field rework to the total construction cost.

STUDY NAME	YEAR PUBLISHED	FIELD REWORK %	NO. OF PROJECTS STUDIED
CII Research Summary 10-1[8]	1989	12% total Design = 9.5% Construction = 2.5%	9 industrial projects
Benchmarking & Metrics Data Report[9]	1997	3.4%	19 industrial projects
Investigation of Field Rework In Industrial Construction – CII Research Report 153-11[10]	2011	4.4%	109 industrial projects
Construction Productivity Research Program Phase III[11]	2011	2% - 20%	Unidentified
The Field Rework Index: Early Warning for Field Rework and Cost Growth[12]	2011	4.4%	153 projects
Costs of Quality Deviations in Design and Construction[13]	1989	17.5% total Construction Deviations = 2.5%	9 industrial projects

STUDY NAME	YEAR PUBLISHED	FIELD REWORK %	NO. OF PROJECTS STUDIED
Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry[14]	2004	1% of sf cost/sf	Unknown
Private interview with Executive of global EPC firm	2012	2% - 5%	35 years of experience with same firm
Causes of Quality Deviations in Design and Construction[15]	1992	Design = 9.5% Construction = 2.5% Fabrication = 0.3% Operability = 0.1%	9 projects
The Causes and Costs of Defects in Construction: A Study of Seven Building Projects[16]	1999	2% - 6%	7 projects
Quantifying the Causes and Costs of Rework in Construction[17]	2000	10% Total Variations = 1.9% Non-Variations = 0.7% Defects = 0.3%	2 projects
Measuring and Classifying Construction Field Rework: A Pilot Study[18]	2003	Direct cost = 0.5% Indirect cost = 0.4% Total cost = 0.9%	1 project
Learning to Reduce Rework in Projects: Analysis of Firm's Organizational Learning and Quality Practices[19]	2003	0% - 35%	Unknown
Adding Value to the Facility Acquisition Process: Best Practices for Reviewing Facility Designs[20]	2000	12.4% total Design errors = 9.9% Construction errors = 2.5%	Unknown
Influence of Project Type and Procurement Method on Rework Costs in Building Projects[21]	2002	12% total	161 projects
Respondent Type			
Designers		Direct Costs = 8.0% Indirect Costs = 6.8%	
Constractors		Direct Costs = 5.8% Indirect Costs = 5.5%	
Project Managers		Direct Costs = 4.3% Indirect Costs = 3.6%	
Total		Direct Costs = 6.4% Indirect Costs = 5.6%	

One of the more recent studies of the causes and cost of rework, which went further in disaggregating projects by type than any other study the Navigant Construction Forum™ located, was performed by Bon-Gang Hwang, Stephen R. Thomas, Carl T. Haas, and Carlos H. Caldas and published in 2009 and titled *Measuring the Impact of Rework on Construction Cost Performance*[22].

This research team studied and included data from some 359 projects of all types and broke down the results into the following:

» Industry Groups
» Project Nature
» Project Size
» Project Location
» Work Type

They then analyzed the average percentage rework by the following nine causes of rework:

» Constructor change
» Constructor error / omission
» Design change
» Design error / omission
» Owner change
» Other
» Transportation error
» Vendor change
» Vendor error / omission

A summary of the findings of this study is set forth below.

INDUSTRY GROUPS

	CAUSE OF REWORK	MEAN TOTAL FIELD REWORK FACTOR
Buildings *(32 projects)* Communication center, courthouse, dormitory, hotel, housing, residential, embassy, hospital, laboratory, office, theater, prison, school, warehouse and other buildings	Constructor change	0.6%
	Constructor error / omission	0.0%
	Design change	0.3%
	Design error / omission	1.5%
	Owner change	1.4%
	Other	0.6%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.1%
	Total	**4.6%**
Heavy Industrial *(102 projects)* Chemical manufacturing, gas distribution, gas exploration/ extraction, metals refining/processing, mining, natural gas processing, oil exploration, production and refining, pulp and paper, power or other heavy industrial	Constructor change	0.2%
	Constructor error / omission	0.4%
	Design change	0.2%
	Design error / omission	1.6%
	Owner change	0.7%
	Other	0.8%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.5%
	Total	**4.5%**

INDUSTRY GROUPS (continued)

	CAUSE OF REWORK	MEAN TOTAL FIELD REWORK FACTOR
Infrastructure *(14 projects)* Airport, electrical distribution, flood control, highway, navigation, rail, tunneling, water and wastewater, telecom/wide area network or other infrastructure	Constructor change	0.1%
	Constructor error / omission	1.0%
	Design change	0.7%
	Design error / omission	0.9%
	Owner change	2.0%
	Other	0.8%
	Transportation error	0.0%
	Vendor change	0.0%
	Vendor error / omission	0.2%
	Total	**5.7%**
Light Industrial *(31 projects)* Automotive manufacturing, consumer products manufacturing, foods, microelectronics manufacturing, office products manufacturing, pharmaceutical manufacturing and labs, clean rooms or other light industrial	Constructor change	0.7%
	Constructor error / omission	0.8%
	Design change	0.1%
	Design error / omission	3.2%
	Owner change	2.8%
	Other	1.2%
	Transportation error	0.0%
	Vendor change	0.2%
	Vendor error / omission	0.3%
	Total	**9.3%**
All Building Types *(179 projects)*	Constructor change	0.3%
	Constructor error / omission	0.4%
	Design change	0.2%
	Design error / omission	1.8%
	Owner change	1.3%
	Other	0.8%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.3%
	Total	**5.2%**

PROJECT NATURE

	CAUSE OF REWORK	MEAN TOTAL FIELD REWORK FACTOR
Add-On *(47 projects)*	Constructor change	0.1%
	Constructor error / omission	0.3%
	Design change	0.3%
	Design error / omission	1.3%
	Owner change	0.8%
	Other	0.4%
	Transportation error	0.0%
	Vendor change	0.2%
	Vendor error / omission	0.2%
	Total	**3.6%**
Grass Roots *(48 projects)*	Constructor change	0.4%
	Constructor error / omission	0.3%
	Design change	0.3%
	Design error / omission	1.3%
	Owner change	0.9%
	Other	0.4%
	Transportation error	0.0%
	Vendor change	0.0%
	Vendor error / omission	0.4%
	Total	**4.0%**
Modernization *(82 projects)*	Constructor change	0.3%
	Constructor error / omission	0.4%
	Design change	0.2%
	Design error / omission	1.8%
	Owner change	1.8%
	Other	1.4%
	Transportation error	0.1%
	Vendor change	0.1%
	Vendor error / omission	0.4%
	Total	**6.5%**
All Projects *(177 projects)*	Constructor change	0.3%
	Constructor error / omission	0.3%
	Design change	0.2%
	Design error / omission	1.5%
	Owner change	1.3%
	Other	0.9%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.3%
	Total	**4.9%**

PROJECT SIZE

	CAUSE OF REWORK	MEAN TOTAL FIELD REWORK FACTOR
<$15 million *(107 projects)*	Constructor change	0.3%
	Constructor error / omission	0.4%
	Design change	0.2%
	Design error / omission	1.4%
	Owner change	1.4%
	Other	0.8%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.3%
	Total	**4.9%**
$15 - $50 million *(49 projects)*	Constructor change	0.1%
	Constructor error / omission	0.4%
	Design change	0.3%
	Design error / omission	1.9%
	Owner change	1.5%
	Other	1.0%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.6%
	Total	**5.9%**
$50 - $100 million *(12 projects)*	Constructor change	0.6%
	Constructor error / omission	0.2%
	Design change	0.6%
	Design error / omission	2.0%
	Owner change	2.2%
	Other	0.9%
	Transportation error	0.0%
	Vendor change	0.2%
	Vendor error / omission	0.6%
	Total	**7.3%**
>$100 million *(7 projects)*	Constructor change	0.1%
	Constructor error / omission	0.1%
	Design change	0.1%
	Design error / omission	0.4%
	Owner change	0.1%
	Other	0.0%
	Transportation error	0.0%
	Vendor change	0.0%
	Vendor error / omission	0.1%
	Total	**0.9%**

PROJECT SIZE (continued)

	CAUSE OF REWORK	MEAN TOTAL FIELD REWORK FACTOR
All Projects	Constructor change	0.3%
(175 projects)	Constructor error / omission	0.4%
	Design change	0.3%
	Design error / omission	1.5%
	Owner change	1.4%
	Other	0.8%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.4%
	Total	**5.2%**

PROJECT LOCATION

	CAUSE OF REWORK	MEAN TOTAL FIELD REWORK FACTOR
Domestic	Constructor change	0.3%
(150 projects)	Constructor error / omission	0.3%
	Design change	0.2%
	Design error / omission	1.5%
	Owner change	1.4%
	Other	1.0%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.4%
	Total	**5.2%**
International	Constructor change	0.4%
(27 projects)	Constructor error / omission	0.4%
	Design change	0.4%
	Design error / omission	1.7%
	Owner change	0.9%
	Other	0.1%
	Transportation error	0.2%
	Vendor change	0.2%
	Vendor error / omission	0.2%
	Total	**4.5%**
All Projects	Constructor change	0.3%
(177 projects)	Constructor error / omission	0.3%
	Design change	0.2%
	Design error / omission	1.5%
	Owner change	1.3%
	Other	0.9%
	Transportation error	0.0%
	Vendor change	0.1%
	Vendor error / omission	0.3%
	Total	**4.9%**

WORK TYPE

	CAUSE OF REWORK	MEAN TOTAL FIELD REWORK FACTOR
Construct Only *(39 projects)*	Constructor change	0.1%
	Constructor error / omission	0.1%
	Design change	0.7%
	Design error / omission	1.1%
	Owner change	0.6%
	Other	0.2%
	Transportation error	0.0%
	Vendor change	0.0%
	Vendor error / omission	0.2%
	Total	**3.0%**
Design and Construct *(132 projects)*	Constructor change	0.1%
	Constructor error / omission	0.2%
	Design change	0.2%
	Design error / omission	0.6%
	Owner change	0.6%
	Other	0.1%
	Transportation error	0.0%
	Vendor change	0.0%
	Vendor error / omission	0.3%
	Total	**2.1%**
All Projects *(171 projects)*	Constructor change	0.1%
	Constructor error / omission	0.2%
	Design change	0.3%
	Design error / omission	0.7%
	Owner change	0.6%
	Other	0.1%
	Transportation error	0.0%
	Vendor change	0.0%
	Vendor error / omission	0.3%
	Total	**2.3%**

Perhaps the most useful aspect of this study is its potential for modeling estimated rework costs for a specific project. For example, a rework estimating model for a hypothetical planned project model is set forth below:

PROJECT CATEGORY	PLANNED PROJECT	MEAN TFRF
Industry Group	Building	4.6%
Project Nature	Modernization	6.5%
Project Size	$50 - $100 million	7.3%
Project Location	Domestic	5.2%
Work Type	Construction only	3.0%
Average Predicted TFRF		**5.3%**

This predicted average TFRF factor would still need to be adjusted for indirect costs and project delay as shown later on in this research perspective.

The Average Cost of Rework

Based upon the above data, the following is an extract of what the Navigant Construction Forum™ believes are the most relevant results of the identified studies.

STUDY	YEAR PERFORMED	MEAN TOTAL FIELD REWORK FACTOR
Hwang – Light Industrial	2009	9.3%
Love — Designers	2002	8.0%
Hwang – $50 - $100 million	2009	7.3%
Hwang – Modernization	2009	6.5%
Hwang – $15 - $50 million	2009	5.9%
Hwang – Infrastructure	2009	5.7%
Love – Contractors	2002	5.8%
Hwang – Domestic	2009	5.2%
Hwang – <$15 million	2009	4.9%
Hwang – Buildings	2009	4.6%
Hwang – International	2009	4.5%
Hwang – Heavy Industry	2009	4.5%
CII Rework Index	2011	4.4%
CII Research Report 153-11	2011	4.4%
Love – Project Managers	2002	4.3%
Josephson	1999	4.0%
Hwang – Add Ons	2009	3.6%
CII Benchmarking Study	1997	3.4%
Hwang – Construction Only	2009	3.0%
CII Study 10-1	1989	2.5%

STUDY	YEAR PERFORMED	MEAN TOTAL FIELD REWORK FACTOR
Burati	1992	2.5%
Spillinger	2000	2.5%
Hwang – Design and Construction	2009	2.1%
Love – Rework: Variations	2000	1.9%
Hwang -- >$100 million	2009	0.9%
Love – Rework: Non-Variations	2000	0.7%
Fayek – Direct Costs	2000	0.3%
Love – Defects	2000	0.3%

Based on a summary of these studies, the **median cost of rework** on average projects is **4.03%**. However, the Navigant Construction Forum™ is reluctant to provide a single point estimate concerning a factor as complicated as the issue of rework. It is noted that the Hwang, Thomas, Haas and Caldas study also commented that:

> "(some)…authors suggest that nonconformance costs may be significantly higher on projects where poor quality management is found."[23]

The 2011 CII study went even further when it commented that:

> "About one third of survey respondents believe that their recorded rework is only 50 – 75% of actual rework experienced."[24]

Based on these comments, the Navigant Construction Forum™ believes that the 4.03% median cost of rework identified above for all types of projects contained in the above referenced surveys, is truly the lower end of a range of costs related to rework – **that range most likely being 4.03% to 6.05% (4.03% x 1.5) with a median of 5.04%.**

Additional Indirect Cost of Rework

The majority of the literature on the subject attempts to determine the direct cost of rework as a percentage of Total Project Cost ("TPC") or TIC. The Navigant Construction Forum™ believes that costs other than direct field rework costs must be considered in order to produce a realistic estimate of the cost of rework. Experienced construction professionals know all too well that field problems on construction projects also incur substantial management costs (overhead costs) while issues are examined and solutions crafted and implemented. For example, the University of Alberta study determined that:

> "…every dollar spent on direct costs [of field rework] for each Alliance member costs $1.72, which includes direct and indirect costs."

The point of this statement is simple but not often considered when reviewing literature concerning the cost of rework. This study noted, properly so, that there is an indirect cost (i.e., field supervision, project management, site safety, etc.) which is in addition to the direct cost of rework (labor, material, equipment and subcontracts).

Another study published in the American Society of Civil Engineers ("ASCE") Journal of Construction Engineering and Management examined the cost impact of rework on projects in Australia. The author used a questionnaire to determine the cost of rework on some 161 projects. This study asked practitioners to estimate the rework costs incurred on their projects – both the direct costs and the indirect costs separately.[25] The following summarizes the results of this study by type of respondent.

RESPONDENT	DIRECT REWORD COSTS AS % OF ORIGINAL CONTRACT COST	INDIRECT REWORK COSTS AS % OF ORIGINAL CONTRACT COST
Designers	8.0%	6.77%
Contractors	5.8%	5.46%
Project Managers	4.3%	3.64%
Mean Rework %	**6.4%**	**5.62%**

This represents an average indirect cost of 87.8% (5.62% ÷ 6.4%) compared to the 72.0% cited in the University of Alberta study. While this markup cost may seem high, when one considers that rework may include re-engineering and reprocurement of parts or material and may also be the cause for project delays, this indirect cost is realistic. The average of these two studies is 79.9%. Based on the research from these two studies the Navigant Construction Forum™ suggests that the average direct cost of rework be "marked up" by 80.0% to reflect indirect costs associated with the estimated direct cost of rework. Thus, the earlier identified range of the direct cost of rework being 4.03% to 6.05% with a median of 5.04%, when adjusted to include indirect costs, reflects a range of 7.25% to 10.89% with a median value of 9.07%.

Schedule Impact of Rework

Love's survey of the cost impact of rework in Australian building projects also noted that, while average cost growth on these 161 projects was 12.6% of the original cost of the project, the average schedule growth due to all causes was 20.7%. In December 2011 the Navigant Construction Forum™, working in conjunction with McGraw-Hill Construction and Pepper Hamilton LLP, published a study focusing on risk mitigation in construction. The study was based on a national survey of project owners, design professionals, construction managers and contractors. One aspect of the survey was to determine what percentage of projects were completed late and by what percentage were these projects delivered later than contracted. This study concluded that 84% of projects were completed late and the average length of project delays was 17% of the planned project schedule.[26] The median project delay time, based on these two studies, equals 18.85% of the planned project duration.

Love's study, which focused on evaluating the impact of rework, concluded that the average cost growth on the projects studied arising from all sources was 20.7%. However, Love also concluded that rework was the cause of 52.1% of the overall cost growth. Assuming that there is an approximate correlation between cost growth and schedule growth it may also be concluded that approximately 52.1% of project schedule growth is likely to result from rework. Based upon the average schedule growth of 18.85% of planned project duration it may be concluded that **rework also results in approximately 9.82%** (18.85% x 0.521) **schedule growth** on the average project.

To determine the cost impact of such schedule delay the Navigant Construction Forum™ performed a short duration private survey of some 50 experienced professionals in the construction industry – including owners, construction managers, attorneys, contractors and claim consultants to estimate the "average cost of a day of contractor delay" and the "average cost of liquidated damages per day".

The Navigant Construction Forum™ survey asked for the survey participants' experience concerning extended field office overhead ("FOOH") costs and Liquidated Damages ("LDs") for a hypothetical project with the following parameters:

Cost = $50 - $100 million (U.S.)

Duration = 2 years – 730 calendar days ("days")

Project Description = Non-revenue generating such as a public building, school, road or highway project.[27]

Some 50 individuals throughout the U.S. were surveyed. Thirty five (70%) responded to the survey but only 24 respondents (48%) were able to provide any useful data. A summary of this survey is set forth below.

- The estimates of daily FOOH delay costs for a contractor on a project such as this had a range of $800/day to $40,000/day. The mean value for the contractor's cost of a day of FOOH delay was approximately $15,000/day.
- The estimates of LDs ranged from $1,000/day to $250,000/day with the mean value of daily LDs being approximately $12,750/day.

Using the information from the two studies cited above an 18.85% delay on this hypothetical project would equal 138 days. If rework represents 52% of this total delay, as reported by Love, then approximately 72 days of this total delay is due to rework. Assuming none of the rework was brought about by owner action or inaction the cost impact of the delay resulting from rework on this hypothetical project equals:

72 days of extended, non-recoverable FOOH @ $15,000/day = $1,080,000

72 days of LDs @ $12,750/day = $918,000

The total potential delay and LD costs owed by a contractor as a result of rework could equal $1,998,000 on this hypothetical project. No matter how large or small the project, the delay costs resulting from rework on any project can be substantial.

Conclusion – Cost & Time Impact of Rework

- **Direct Cost of Rework** – Based upon the literature analyzed the Navigant Construction Forum™ has determined that the median direct cost of rework on capital improvement projects is 4.03% of original contract cost according to published studies. But due in large part to under reporting of rework costs the Navigant Construction Forum™ believes that the 4.03% median cost impact is most likely the lower range of direct costs due to rework with the **actual range being between 4.03% and 6.05% with a median value of 5.04%.**
- **Indirect Cost of Rework** – The Navigant Construction Forum™ is cognizant that field direct costs must carry a share of the field and home office costs required to support a project. Thus, the direct costs incurred while performing rework must be marked up appropriately. Love's study and the study performed by the University of Alberta (both cited previously) indicate that for every dollar of direct cost incurred on rework there is an indirect cost of approximately 80%. **Therefore, the estimated direct cost range of 4.03% to 6.05% should be adjusted by a factor of 1.8 to account for indirect costs incurred as a result of direct rework costs revising the range of total rework cost 7.25% to 10.89% with a median value of 9.07%.**

- **Schedule Impact of Rework** – As discussed above, field rework consumes time on any project. Setting aside temporarily the issue of the cause of rework, the Navigant Construction Forum™ has determined, again based on published studies, that the **average delay incurred on projects is approximately 19% of the original project schedule.** Based upon Love's study approximately 52% of project delay typically results from rework activities. Therefore, it can be concluded that **rework typically results in a 9.82% schedule growth.** To put this in more practical terms, assuming a project with a two year (730 calendar days) planned duration rework is likely to generate a 72 day delay.
- **Delay Cost of Rework** – The Navigant Construction Forum™ recognizes full well that there are many variables concerning projects – size, location, complexity, duration, delivery model, etc. Despite these variables, it appears clear that rework can cause substantial schedule growth on a project which, in turn, can result in substantial delay costs. Such delay costs, under most contracts, are classified as contractor caused delay and as such are typically not recoverable costs. These delay costs include extended home office and field office overhead, extended labor and equipment costs and the payment of either liquidated or actual damages due to contractor caused delay. In considering the impact of rework on projects the delay cost resulting from rework must also be taken into consideration. While this research perspective has attempted to illustrate this fact through use of a hypothetical project, such a calculation can easily be run on any construction project.
- **Potential Trend Concerning Rework Costs** – Finally, if one examines the chart shown on page 23 of this research perspective it appears that older studies carried smaller estimates of the impact of rework than the more current studies. The nine studies performed between 1989 and 2000 resulted in a 2.01% TFRF while the 20 studies performed between 2002 and 2011 demonstrated a 5.21% TFRF – a drastic increase of 259%. While there are no studies specifically oriented at this issue as yet, the Navigant Construction Forum™ believes that the lack of skilled, qualified craft labor may be responsible for some of the increase in rework. That is, there may be a correlation between the percentage of rework and the lack of skilled labor. As the experience and skills of the labor crews in the field go down, the likelihood of rework is likely to react inversely.

Some Practical Remedies

The Navigant Construction Forum™ believes that both owners and contractors have a vested interest in preventing field rework on projects. Contractors who can decrease rework on projects should decrease, to some extent, time and cost overruns on their projects and, in turn, increase profitability. Owners likewise can profit from a decrease in the need for rework through decreased time to complete projects allowing earlier occupancy and use; an increase in the quality of the constructed project; and potentially avoid some disputes concerning responsibility for cost overruns.

During the preparation of this research perspective the Navigant Construction Forum™ has considered some practical ways and means to avoid the need for rework on projects. The Navigant Construction Forum™ recognizes the in the Design-Bid-Build ("DBB") environment contractors have almost no involvement in or control over the quality of the design documents put out to bid. However, owners and their design professionals and construction managers do. Thus, the recommendations below are oriented primarily to owners and their representatives. On the other hand, in the Design/Build ("D/B") or Engineer Procure Construct ("EPC") world contractors are fully capable of employing some or all of the recommendations set forth below. Taken as a whole, the following recommendations are offered as suggestions for avoidance of rework, regardless of whether the rework is caused by the owner, the contractor, suppliers, vendors, etc. With this in mind the Navigant Construction Forum™ offers the following recommendations for consideration.

Use of Building Information Modeling ("BIM") and Virtual Design & Construction ("VDC")

BIM, as an umbrella term, has come to encompass the entire spectrum of emerging tools (software), processes (VDC) and methods (*non-traditional* contracts) across a project's complete lifecycle - from design, through construction and on to facilities management and operations. Said another way, the world of BIM/VDC is very large and definitions and perspective vary greatly depending upon whom you ask. Accordingly, this discussion focuses exclusively on the "3D" (geometric) and "4D" (time) benefits of BIM/VDC and offers only high level summary review of how BIM/VDC can be utilized to prevent the need for rework.

3D clash detection, a frequent use of BIM/VDC, has direct implications in reducing potential costs and schedule delays associated with rework. By building a project twice – once digitally, in a virtual environment before actually bringing shovel to dirt in the real world – a project team reaps the benefits of pre-construction clash, coordination, and constructability review, thereby diminishing potential rework. Utilizing BIM/VDC software that is specifically designed to compile all individual 3D geometric models from all stakeholders, contractors can locate and isolate clashes/collisions between trades and systems in 3D space, then use the management features of the software to track any collisions through to resolution, all before mobilizing trade labor to the site. While it is unrealistic to imagine any job being error-free, a rapidly expanding body of research points to significant reduction in costs and schedule delays associated with rework on projects that implement BIM/VDC.[28] The direct project experience of the Navigant Construction Forum™ supports similar findings. Additionally, the December 2011 Navigant Construction Forum™, McGraw-Hill Construction, Pepper Hamilton LLP, risk mitigation study also included nearly identical findings.[29]

4D BIM/VDC (3D + Time) links together the geometric objects in a project's model(s) with the project's schedule and, like clash detection, offers direct ways and means to avoid rework. Using specialized BIM/VDC software (in some cases the same software programs described above for use in clash detection) a contractor is able to connect discrete tasks in a project's schedule with the corresponding object or construction assembly in a compiled BIM. At the most basic level, envision a project schedule with four distinct tasks; construct walls 1 through 4, each with a given start and end date. Then imagine connecting each scheduled task (e.g., Construct wall #1, Construct wall #2, etc.) to the corresponding digital 3D walls in a model. With tasks and objects now connected, the end result allows the contractor to animate the schedule over time. In short, a time lapse film of the erection sequence now exists. In addition to "pressing play" to watch the digital construction unfold from beginning to end, a contractor can also select any future (or past) date in the schedule and be presented with a 3D visual image of what the project should look like at that point in time. The benefit of this process is to decrease opportunities for rework by enabling the contractor to coordinate complex sequencing and phasing issues, evaluate site logistics, staging and workflows, and visually identify any potentially hidden logic flaws in the schedule. Utilizing the schedule-to-BIM link as a window into the future, the contractor is able to avoid potential schedule delays, whether the root cause is driven by rework or other factors. As with clash detection, emerging case studies and the direct project experience of the Navigant Construction Forum™ support findings showing real benefit of BIM/VDC to reductions in schedule delay related to rework.[30]

BIM/VDC presents practical ways and means to reduce the need for rework if implemented in a comprehensive and collaborative manner from the pre-planning stages of a project. While BIM/VDC cannot address every potential cause of deviation resulting in the need for rework (e.g., design change/owner, design change/field, etc.) common logic, now supported by growing research metrics, points towards real cost and schedule delay savings through its implementation.

Early and Continuous Stakeholder Involvement

It is the experience of the Navigant Construction Forum™ that many change orders issued toward the end of a project (i.e., during the startup, commissioning or transfer of care custody and control phase) are actually the result of the failure to include various stakeholders in the planning and design process. All too frequently preventable changes occur when stakeholders see the project for the first time when construction is nearly complete. Change orders at this phase of a project typically are very expensive, more disruptive than earlier issued changes and frequently involve rework in the form of removal of some of the work previously completed to implement the change. The most obvious practical suggestion to help avoid this situation is to identify, during the planning phase, all stakeholders who will occupy and/or maintain the project after it's put into use or operation. These stakeholders must be continuously involved in project planning and design to make certain their needs are met by the completed project.

Design Freeze Prior to Start of Construction and Delegation of Authority

Once stakeholder agreement on the project design is reached, the design must be "frozen" thus precluding a number of project changes as stakeholders reconsider their earlier agreement on the project design. This should help reduce rework on a project resulting from project changes. The owner must appoint a single project representative (the "project czar", the owner's project manager) to manage the relationship with the contractor. Only the project czar should be allowed to communicate with the contractor during construction and only this individual should have the delegated authority to agree upon and issue changes during construction.

Biddability Review

The Navigant Construction Forum™ believes some rework is caused by unclear scope definition at the start of construction. In such situations construction may start with an unidentified disagreement over the work scope. That is, both the contractor and the owner commence construction believing they understand what is required to successfully deliver the project and only later learn that they each have a differing interpretation of the project requirements. This misunderstanding may result in the need for rework involving removal and replacement of work already installed in order to complete the project in accordance with the owner's actual needs. To ensure that the information provided to bidders is clear and adequately covers all aspects of the project's scope of work, owners would be well advised to retain the services of a contractor or professional construction manager (who was not involved in the planning or design of the project) to examine the project documents. The purpose of this review is to ascertain whether the information provided will allow a contractor to bid intelligently and ultimately deliver what the owner really needs.

Constructability Review

Similarly, the Navigant Construction Forum™ recommends using an independent consultant or a contractor to review the project documents and perform a constructability review. Such a review is defined as an examination of documents to determine whether there is sufficient information to allow the contractor to build the project without questions or changes prior to bidding. If the need for project change is alleviated prior to bidding then a substantial tranche of rework should be avoided. Again, the team performing this review should not have been involved in the planning or design of the project.

Operability Review

As mentioned earlier, it is critical to involve all project stakeholders. However, if the capital improvement project involves an operating facility (e.g., water or wastewater treatment facility, power plant, petrochemical plant, etc.) the Navigant Construction Forum™ recommends that key operations personnel be assigned fulltime to the planning and design phase of the project. Such an assignment should help prevent some rework by ensuring that operational needs are adequately incorporated during the planning and design phases and not added via changes during construction. Further, key operating personnel should be assigned to the owner's project management team to deal with changes and potential changes – making certain that changes do not adversely impact operational needs and thus avoiding some rework to deal with operations problems caused by changes during construction.

Change Order Review

Many project owners are "serial builders" – owners who construct projects routinely year in and year out. For such owners, the Navigant Construction Forum™ believes that a review of changes issued on previous projects can provide an index of issues that can be used to examine new projects. If the same issues that caused changes on previous projects are found in a new project design, such issues can be corrected before construction starts. This will help reduce the need for rework due to changes during construction.

Conclusion

Average rework on projects can cost between 7.25% and 10.89% of total construction cost (when both direct and indirect costs are included) and can cause an increase in the schedule (project delay) of approximately 9.8% of the planned project time. The Navigant Construction Forum™ believes that there are a number of practical ways to reduce the need for rework if they are employed from the outset of the project.

Future Efforts of the Navigant Construction Forum™

In the third quarter of 2012, the Navigant Construction Forum™ will continue its analysis of construction industry issues. The Navigant Construction Forum™ is in the process of conducting a survey of current trends in arbitration in the construction industry. It is believed that the results of this survey will enable construction industry participants to become more attuned to such new trends.

Further research will continue to be performed and published by the Navigant Construction Forum™ as we move forward. If any readers of this research perspective have ideas on further construction dispute related research that would be helpful to the industry, you are invited to e-mail suggestions to jim.zack@navigant.com.

1. Associate Director, Navigant Consulting, located in Philadelphia, PA.
2. Associate Director, Navigant Consulting, based in San Francisco, CA.
3. Executive Director, Navigant Construction Forum™, *"The industry's resource for thought leadership and best practices on avoidance and resolution of project disputes globally"*, stationed in Irvine, CA.
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